

NASA Glenn Propulsion Systems Lab (PSL) Icing Facility Update

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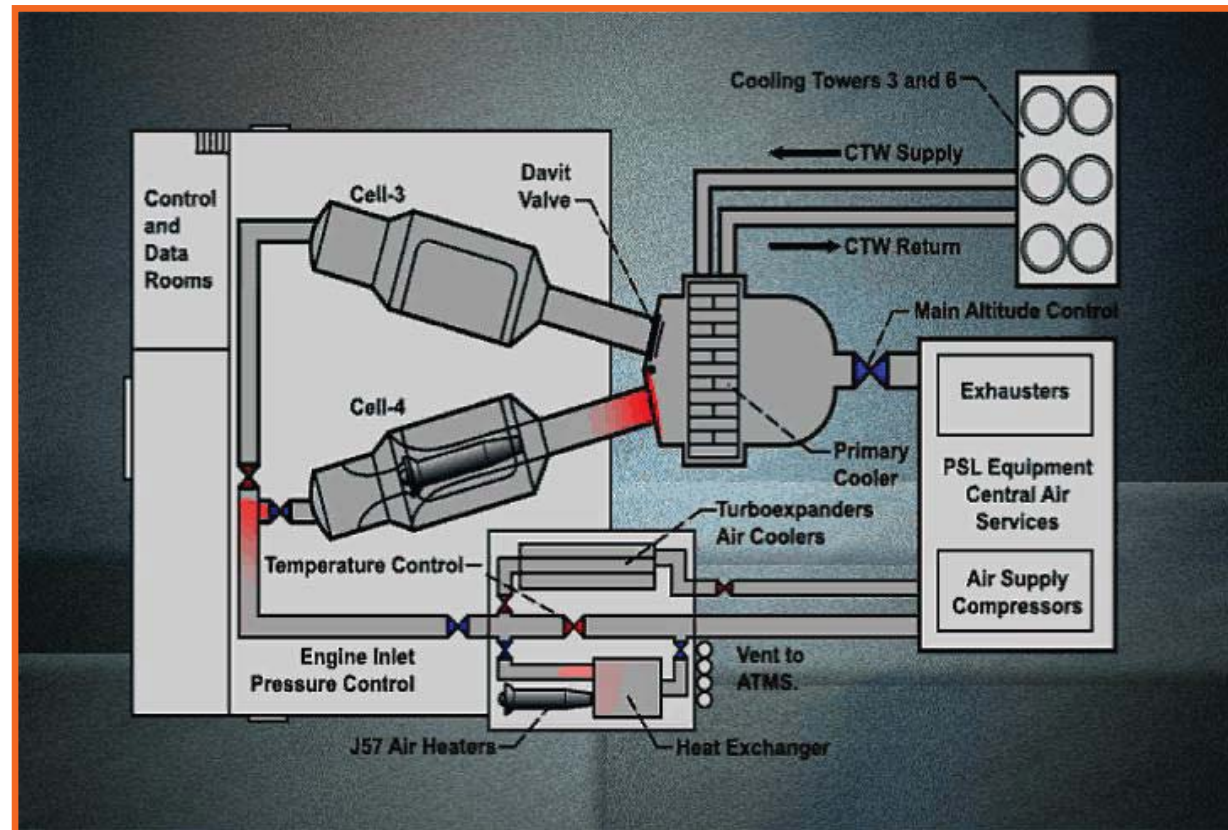
Outline

- PSL Background
- Icing System Design
- Facility Modification
- Calibration/Validation
- Further Enhancements

PSL Background

NASA PSL is one of the Nation's Premier Direct Connect Altitude Simulation Facilities for Full-Scale Gas Turbine Engine and Propulsion System Research

- Two test sections share common inlet and exhaust
- Continuous Operation at high air flow rates
 - Altitude 90,000 ft (-90 deg F)
 - PSL-3 Mach 3.0 (600 deg F)
 - PSL-4 Mach 4.0 (1200 deg F)
- PSL3 recently upgraded for icing capability
- Multi-axis thrust measurement
- Real time, high speed data acquisition and display



NASA PSL Icing Status

- Initial icing calibration completed Nov. 2012
- Inaugural icing test of Honeywell ALF502-R5 engine completed April 2013.
- Second icing calibration completed June 2014.
- Second icing test planned for Nov-Dec 2014.

Icing System Design

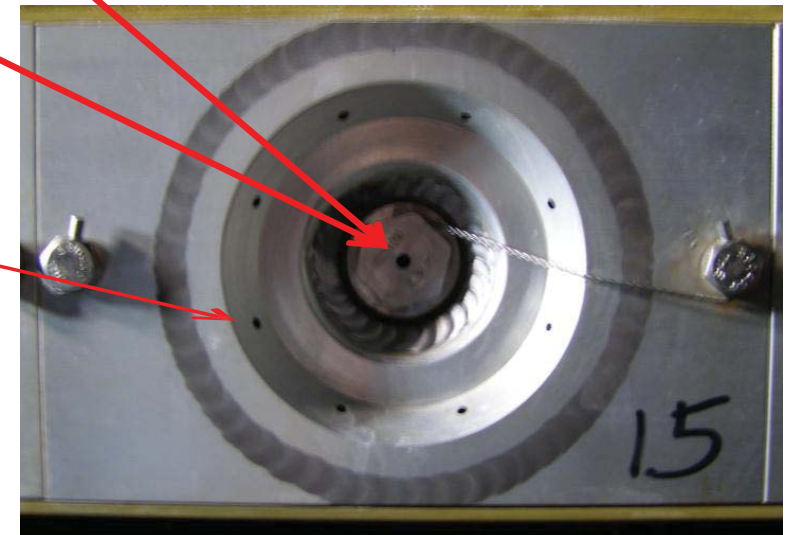
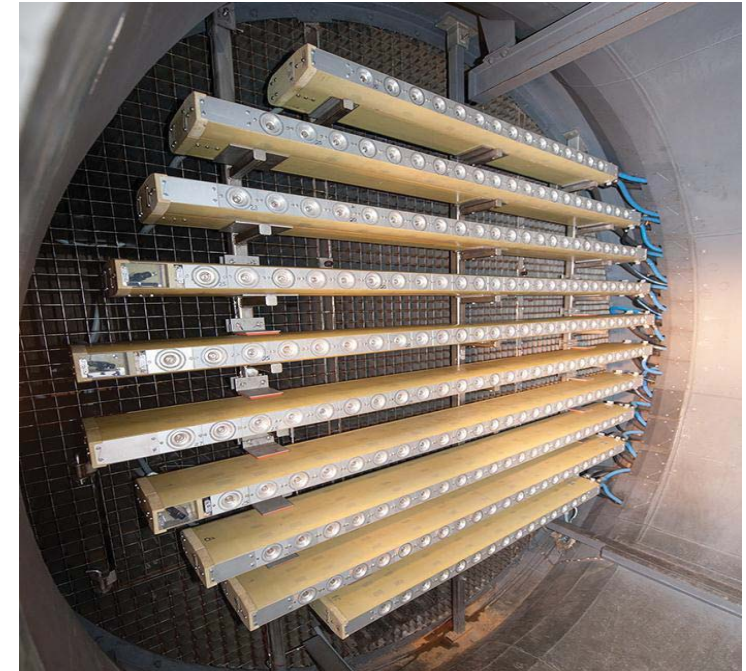
Specified Requirement		
Specification	Minimum	Maximum
Altitude (pressure)	4000 ft	40,000 ft
Inlet Total Temperature	-60°F	15°F
Mach Number	0.15	0.80
Air Flow Rate	10 lbm/sec	330 lbm/sec
IWC (icing water content)	0.5 g/m ³	9.0 g/m ³
MVD (median volumetric diameter)	40μ	60μ
Run Time	Continuous up to 45 minutes	

These were the design requirements for the icing system. We have demonstrated expanded capability during the first calibration test.

PSL Icing Cloud Hardware

Spray Bars – Cloud Generation

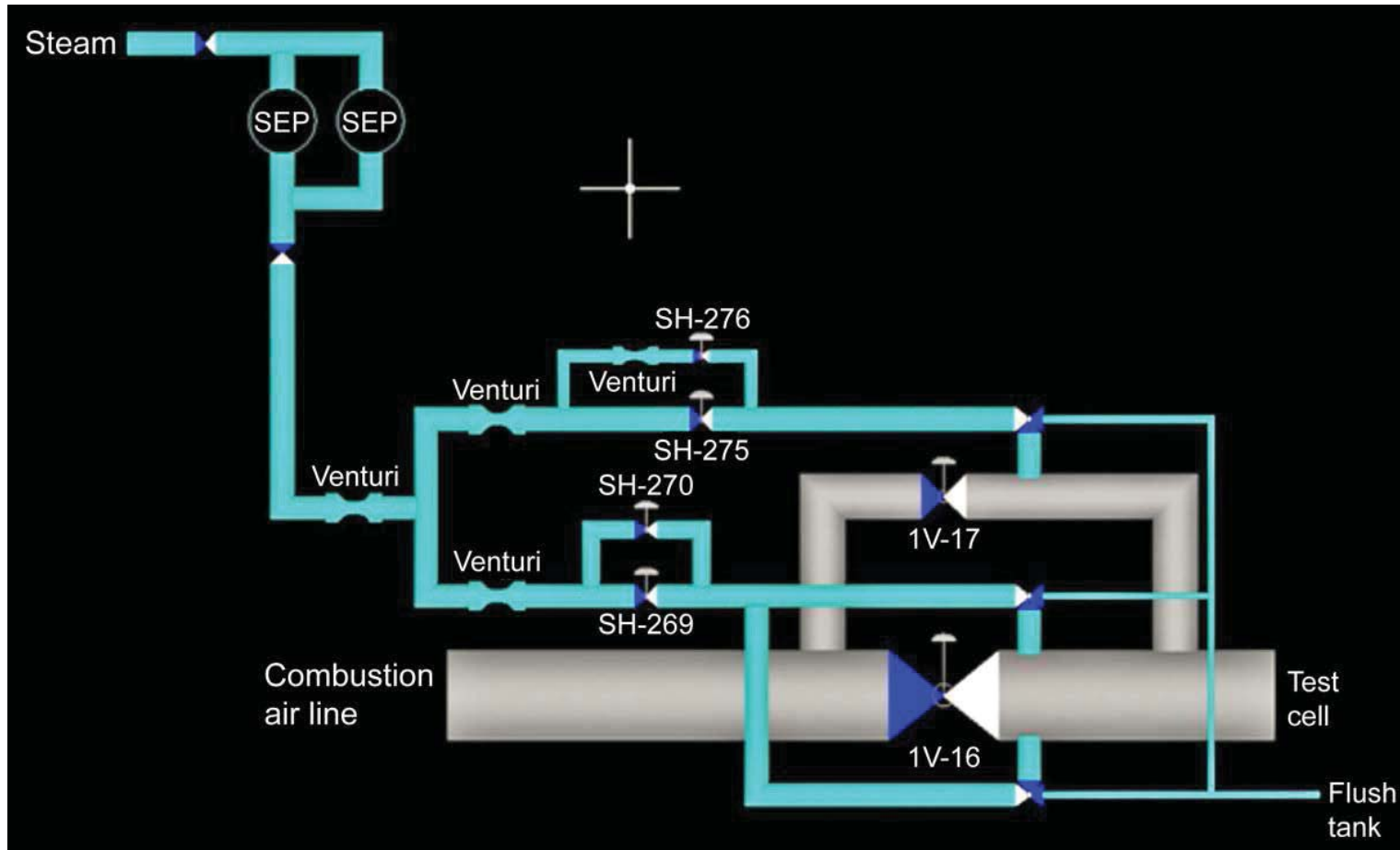
- Ten Spray Bars; total of 110 **Standard** nozzles and 112 **Mod1** nozzles.
- Each nozzle is individually controlled.
- Nozzle controls:
 - **Pair**, atomizing air pressure: 10 – 90 psid, Tair temperature: 45 – 180 F.
 - **Pwat**, water pressure: 10 – 300 psid, Twat temperature: 45 – 180 F.
 - **DeltaP** = DP = (Pwat – Pair)
 - SBCA, Spraybar cooling air.
P: 5 – 40 psid, T : -40 – 40 F.



$(Pair, \Delta P) \Rightarrow (MVD, TWC)$

At a given air mass flow rate

Facility Modifications



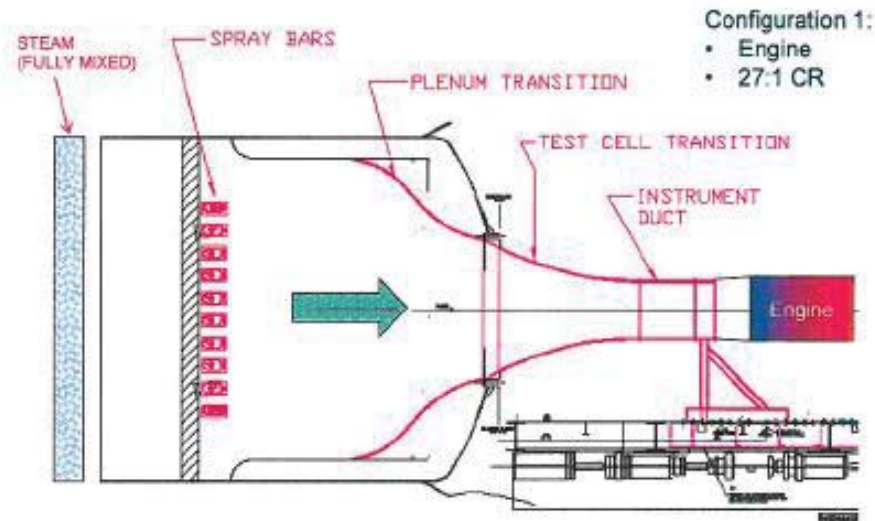
Steam Injection System is used to provide a constant relative humidity in the inlet plenum to stabilize cloud.

Steam is injected into the inlet airstream as the supply air enters the building.

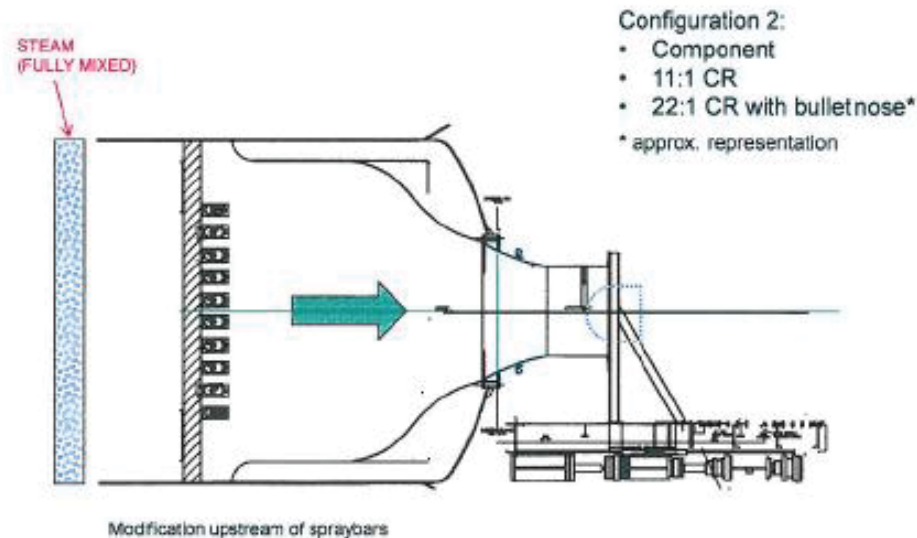
Relative humidity is measured at the injection point and in the inlet plenum.

Icing Calibration Configurations

PSL Configuration – 1st Cal



PSL Configuration – 2nd Cal



PSL Clouds

- Ice Crystals
 - Cold spraybar air & water temps
 - City or De-ionized water
 - Fully glaciated upto MVD 100 um
 - Wet Bulb temp < 0 C
- Supercooled Liquid
 - Hot spraybar air & water temps
- Supercooled Large Drops (SLD), but not bimodally distributed.

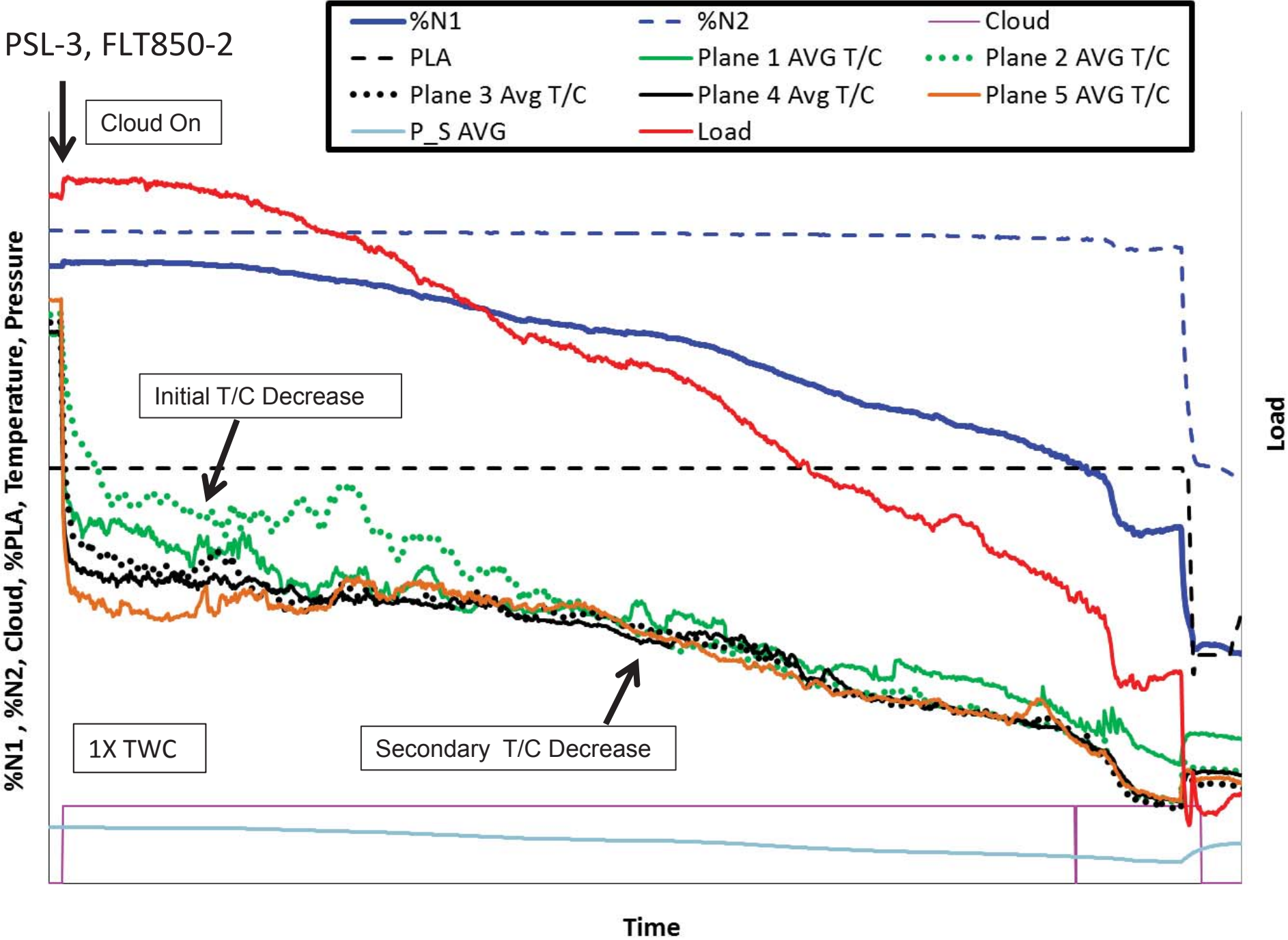
Inaugural Engine Icing Test

Honeywell ALF502R-5 engine installation in PSL. Validation test was able to replicate both roll back and non-roll back events previously experienced by the engine in flight test.



Rollback Indicators Chart- roll back test point

PSL-3, FLT850-2





Questions?/Comments !

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